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Coyote predation on domestic sheep deterred with electronic dog-training collar

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Abstract Additional methods are needed to deter predators from killing livestock. We tested the effectiveness of an electronic dog-training collar to deter captive coyotes (*Canis latrans*) from killing domestic lambs by shocking coyotes whenever they attempted to attack lambs during a 22-week period. The collar averted all 13 attempted attacks on lambs by 5 coyotes, greatly reduced the probability of subsequent attempted attacks, and caused coyotes to avoid and retreat from lambs for over 4 months (F=16.28; 1,4 df; P=0.016). We believe this approach to aversive conditioning has potential to reduce coyote predation on domestic sheep in limited areas and may apply to a variety of other problems involving carnivore predation on domestic or endangered species.

Key words aversive conditioning, behavior, *Canis latrans*, control, coyote, damage, electrical shock, livestock predation

Predators kill significant numbers of sheep, goats, and calves in the United States despite various types and intensities of predator management used by producers and professional wildlife managers to reduce depredations (National Agricultural Statistics Service 1991, 1995; Andelt 1996). With changing public sentiment about the way wildlife damage is managed and the loss of some lethal control techniques, additional methods are needed to manage predation on livestock by carnivores.

Gustavson et al. (1974) proposed and tested conditioned taste aversion using lithium-chloride-treated baits and carcasses to prevent coyotes (*Canis latrans*) from killing lambs. The effectiveness of this tactic has been intensively researched (Gustavson et al. 1974, Burns and Connolly 1980, Burns 1983*a*, Conover and Kessler 1994), and results have been controversial (Burns and Connolly 1985; Forthman Quick et al. 1985*a*, *b*; Lehner and Horn 1985). Our assessment of the research indicates that coyotes acquired bait aversions but generally did not develop an aversion to live prey after feeding on sickness-producing baits and carcasses. Various applications of aversive chemicals to the necks or bodies of sheep have been unsuccessful in establishing aversions to live prey in coyotes (Burns 1983*b*, Burns and Mason 1996).

Linhart et al. (1976) used a prototype electronic collar to condition 3 of 4 coyotes to avoid black domestic rabbits while continuing to prey on white rabbits, and thus provided one of the few successful applications of aversive conditioning in coyotes. Electric shock has been used to establish aversions to visual and gustatory stimuli in albino rats (Krane and Wagner 1975). Electronic collars and electronic ear tags also have been used to train cattle to avoid certain portions of pastures, such as riparian areas (Quigley et al. 1990, Tiedemann et al. 1998). Our objec-

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Figure 1. Coyote chasing a domestic lamb. Photo by William F. Andelt.

tives were to determine if an electronic dog-training collar could condition captive coyotes to stop killing domestic lambs and to place the results in the context of other attempts at aversive conditioning.

Methods

This study was conducted at the National Wildlife Research Center's Predator Research Facility near Logan, Utah. We transported 20 Rambouillet lambs to the research site on 30 April 1997. We placed lambs in a pasture with shelter, feed, and water.

We attempted to select captive coyotes that had previous experience killing lambs, were similar in age, and were not being used in other studies at the facility. We selected 5 male and 4 female coyotes between 5 and 9 years old. Male 5037 had previous experience attacking and wounding a lamb; the other coyotes previously were not allowed to attack

Figure 2. Coyote walking near domestic lamb. Photo by William F. Andelt.

lambs. On 5 May, we moved the 9 coyotes to individual 4.5-m^2 kennels under an elevated observation tower from which we conducted observations of coyote–lamb interactions in a 679-m^2, trapezoid-shaped enclosure. We released each of the 9 coyotes into the enclosure with 1 lamb during a 2-hour pretrial period on 6 or 7 May 1997, to select at least 5 coyotes that readily performed lethal attacks on lambs. Four males, but no females, attacked, killed, and partially consumed lambs during the initial period, and the fifth male (5162) exhibited this behavior when it was solely retested on 13 May; we used these 5 males in our electronic collar trials. We provided coyotes water *ad libitum* and fed them 1 unskinned front or hind quarter of a lamb/day for 4 days after killing the lamb in the pretrial to enhance experience with sheep as a food source. Thereafter, we fed coyotes approximately 600 g of commercial mink food daily; during electronic collar testing, we fed coyotes after the trials.

We restrained coyotes by hand while we attached collars. On 6 and 7 May, we placed non-electronic "dummy" collars (Tri-Tronics, Tucson, Ariz., USA), which were the same size, shape, and weight as the test collar on the 4 coyotes that killed lambs (and on 13 May we placed a "dummy" collar on the coyote that killed a lamb on 13 May), to acclimate them to the training collar. On the first day of electronic collar testing, we permanently removed the "dummy" collars and clipped the neck hair of coyotes to ensure that electrical contact with the electronic collar would be maintained throughout the study. Coyotes 5348 and 5366 were aggressive and difficult to handle, thus we gave them 0.5–1.5 ml of ketamine hydrochloride to facilitate attaching and removing the collar 1–24 hours before trials and immediately after trials beginning on 15 and 20 May, respectively. Both coyotes appeared fully recovered from the effects of ketamine hydrochloride before we tested them with lambs. We used 1 Model 100 Lite electronic dog-training collar (Tri-Tronics, Tucson, Ariz., USA), adjusted to deliver the maximum intensity shock; used the highest power setting on the radiotransmitter, which resulted in 325 pulses/second of 600–640 volts and about 0.032 ampere of instantaneous current (D. V'Marie, Tri-Tronics, Tucson, Ariz., USA, personal communication); and removed the collar after each trial.

We placed 1 lamb in the test area and a decoy lamb in a 1.0 x 0.75-m cage approximately 1 m outside the enclosure to attract the test lamb to an easily observed area. We tested each coyote during 2-

Table 1. Number of attacks (all averted with the electronic shocking collar) on domestic lambs by captive coyotes near Logan, Utah, May–October 1997.

		Coyote				
Date[a]	Week	5348	5162	5037	5366	5157
13 May	1	0	Not tested[b]	3[c]	2	1
14 May	1	1	1	0	1[d]	1
15 May	1	0	0	Not tested	Not tested	Not tested
20 May	2	0	0	0	0	0
21 May	2	0	1	0	0	0
3 June	4	0	0	0	0	0
4 June	4	0	0	0	0	0
24 June	7	0	0	0	0	1
25 June	7	0	0	0	0	0
22 July	11	1	0	0	0	0
23 July	11	0	0	0	0	0
26 August	16	0	0	0	0	0
27 August	16	0	0	0	0	0
8 October	22	0	0	0	0	0
9 October	22	0	0	0	0	0

[a] Trials on 13-15 May were 2 hrs, whereas the other trials were 1 hr.

[b] We tested coyotes on 2 consecutive days each week, except coyote 5348, which was tested on 3 consecutive days of the first week because it may have become fatigued on the first day when we struggled with it while attaching the electronic collar.

[c] One attack occurred during the second hr of testing.

[d] The attack occurred during the second hr of testing.

hour periods on 2 consecutive days (except coyote 5348, which was tested on 3 consecutive days because it may have become fatigued when we struggled with it attaching the electronic collar on the first day) during the first week of our trials. We continued testing each coyote for a 1-hour period on each of 2 consecutive days during weeks 2, 4, 7, 11, 16, and 22 to determine the duration of the aversive conditioning. We attempted to avert all attacks on the lamb during all trials by delivering a 1- to 3-second, continuous or briefly interrupted shock to the coyote each time it actively pursued and was within 5 m (usually within 2 m) of the lamb or when the coyote closely approached the lamb from the rear and attempted to bite it. We considered 1 pursuit to cease and another to begin if the former was interrupted by a shock(s). We defined 1 attack as all pursuits that occurred within 30 seconds; all pursuits that were part of the same predatory sequence occurred within this interval. We exposed individual lambs to coyotes on 1-3 days of trials and to 1-3 coyotes on a given day if tested during the first 5 trial days and to all 5 coyotes if tested after the fifth trial day. We used logistic regression with a logit link and a binomial distribution (SAS Institute, Inc. 1993) to determine if the probability of an attack by the 5 coyotes during the first hour of testing decreased during the study.

Results

Four of 5 coyotes attempted 7 attacks on individual lambs during the first trial on 13 or 14 May (Table 1). The 4 coyotes initially pursued lambs an average of 3.4 minutes (range=0.2-6.2 min) after being introduced into the test area. Coyote 5348 did not attempt an attack. Coyotes 5162 and 5157 actively pursued lambs 2 and 4 times, respectively, within 20-second periods (defined as 1 attack each); we shocked both coyotes during each pursuit, and

Figure 3. Coyote interacting with sheep. Photo by Guy E. Connolly.

Figure 4. Coyote pursuing a lamb and ewe. Photo by Guy E. Connolly.

both quickly recovered and continued active pursuits until we administered the last shock. Coyote 5366 pursued the lamb, was averted with a shock, slowly approached the front of the lamb 21 minutes later, and again was averted with a shock. Coyote 5037 pursued the lamb, was averted with a shock, immediately pursued the lamb, and again was averted. This coyote pursued the lamb 2 and 86 minutes later and each time was averted.

We retested the 5 coyotes on 14 or 15 May, 1 day after the first trial (Table 1). Two coyotes (5162, 5037) did not pursue lambs. The coyote (5348) that did not attempt to attack a lamb on the previous day actively pursued a lamb 9.8 minutes after the trial began and was averted with a shock. Coyote 5157 slowly approached a lamb from the rear and nipped at the lamb's flank. Coyote 5366 slowly approached a lamb from the rear and suddenly seized it by the hock before we were aware that it was going to attack. We averted both attempted attacks by an electric shock, and neither lamb was injured by the coyotes. During the first week (on 15 May), we tested coyote 5348 a third time and it did not attempt an attack. Only 3 attempted attacks by 3 different coyotes occurred during the remainder of the study, and each was averted by a shock from the training collar. The probability of an attempted attack by the 5 coyotes during the first hour of testing decreased (F=16.28; 1,4 df; P=0.016) during the study (Table 1). To minimize potential confounding effects of increasing size of lambs (5 and 4 randomly selected lambs weighed an average of 13.1 kg on 14 May and 32.9 kg on 24 August 1997) on the probability of an attempted attack, we also analyzed the first month of testing separately and found that attacks also decreased during that period (F=18.44; 1,4 df; P=0.013). The last attempted attack by each coyote occurred an average of >4 months before the end of the study (Table 1).

Coyotes appeared to alter their behavior toward lambs in response to being shocked. During the first day (13 or 14 May) that each coyote attempted an attack, 7 of the attacks consisted of active chases of lambs, whereas 1 (the second attack by coyote 5366) consisted of a slow frontal approach. During subsequent trials, coyotes slowly approached lambs and attempted to bite or nip the flank area on 3 occasions, quickly circled a lamb and attempted to bite the flank on 1 occasion, and ran at a stationary lamb on another occasion. During the first day each coyote attempted an attack, 3 of the attacks consisted of 2–4 consecutive chases that were interrupted with shocks; no consecutive chases occurred in subsequent trials. Before being shocked, coyotes did not tend to avoid lambs, but after being shocked, they often avoided lambs and retreated when a lamb approached; during 2 retreats, coyotes 5348 and 5037 displayed submissive behaviors.

Most shocks that we administered during active pursuits resulted in an immediate interruption of an attack. During slow approaches and flank bites or nips, coyotes quickly backed away from the lambs after being shocked. None of the coyotes contacted lambs immediately after being shocked.

Discussion

Coyotes appeared to quickly associate the shocks from the electronic collar with their attempted attacks on lambs. Our training sequence with the collar stopped all attempted attacks, and altered coyote behavior toward lambs by decreasing the probability of an attempted attack, eliminating consecutive chases, causing switches from active pursuits to sneaking behind lambs and attempting to bite or nip the flank area, and causing avoidance of lambs. This reduction in attacks and the >4-month average duration between the last attempted attack and the end of the study indicate that our approach to aversive conditioning had lasting effects.

We believe prey-killing aversion can be most readily established by applying response-contingent aversive stimuli during the chase and attack phase of the predatory sequence (Burns and Connolly 1980), as in this study. In contrast, we believe that conditioned taste aversion (Gustavson et al. 1978) generally has not led to rejection of live prey under practical field applications (Burns and Connolly 1980, Burns 1983*a*) because coyotes apparently rely primarily on visual stimuli rather than taste and odor stimuli (Olsen and Lehner 1978, Wells and Lehner 1978) when capturing prey, and thus may have difficulty associating a live animal with an aversive bait.

Our results and those of Linhart et al. (1976) differ from Burns et al. (1984), who reported coyotes apparently did not learn to avoid sheep after receiving repellent or aversive chemicals in neck collars. We suspect that these results differ because we and Linhart et al. (1976) conditioned most coyotes 2–6 times with substantial response-contingent shocks during the pursuit of prey, whereas Burns et al. (1984) conditioned coyotes less frequently, post-ingestional illness may have been a less severe stimulus, and application of the stimulus often was delayed until after the predatory event. Also, neck collars containing sublethal doses of sodium cyanide or capsicum oleoresin on sheep or lambs were not effective to control coyote predation because coyotes redirected attacks at the sides and rear of lambs after puncturing a collar (Burns et al. 1984, Burns and Mason 1996). We noted that coyotes redirected their attacks after being shocked, but a major advantage of the electronic collar was that it allowed us to avert all attacks.

We did not use a control group of coyotes during our study to better establish the duration of aversive conditioning, because of animal care and use concerns about allowing coyotes to kill a large number of lambs. To remove the potentially confounding effect of increasing size of lambs, separate control groups of 5 coyotes each would have been needed for testing during each of the 14 (or perhaps several) trials so that treatment and control coyotes would have had similar experience killing lambs. To alleviate some of this concern, we noted that coyotes significantly decreased the probability of attacks during the first month of testing when lambs did not grow substantially. Additionally, O'Gara et al. (1983) reported that coyotes continued killing lambs as they increased in size, and coyotes also killed adult ewes when lambs were present. In retrospect, if lambs become less vulnerable to coyote predation as they increase in size, then our aversive conditioning was still successful during the vulnerable period.

Research and management recommendations

Electronic training collars likely will have somewhat limited applications for resolving conflicts with predators; the effectiveness of these applications will need to be confirmed in the field. Primary applications will be where the extent of depredations or the value of the predator or the animals to be protected can justify the costs of equipment, capturing the predator, and possibly capturing the animals to be protected.

An electronic collar and transmitting unit will need to be developed for practical use in the field. The collar should retain battery power for an extended period of time, and should maintain contact with the predator without causing irritation. The transmitting unit should be versatile so that it can be placed directly on the prey or at a fixed location so it automatically activates the collar as the predator approaches. Coupling a frightening auditory stimulus to the shocking event may encourage the predator to move away from the transmitting unit and may help the animal learn avoidance. A remote transmitting unit and electronic ear tag have been developed which meet some of the above characteristics (Quigley et al. 1995).

Coyotes are territorial, such that a few individuals have relatively exclusive access to lambs and other prey in those territories. This suggests that research is needed to ascertain if only a few individuals need to be captured, collared, and aversively conditioned to protect lambs or endangered species such as black-footed ferrets (*Mustela nigripes;* Biggins et al. 1998) in those territories. Where coyotes kill large prey, adult males might be preferentially conditioned because 2-yr-old males (Connolly et al. 1976) and alpha males (Gese and Grothe 1995) were more prone to kill larger prey than were younger males, females, and coyotes of lower social status.

Coyotes without hunting or prey-killing experience kill sheep (Connolly et al. 1976). However, the role of parental influence and social learning on prey selection may be important in coyotes, as it is in several other species (Bekoff 1977, Heyes and Galef 1996). Thus, research is needed to determine if pups of conditioned coyotes will learn, through parental facilitation or observational learning (Sterner 1997), to avoid sheep and endangered species. If such learning occurs, the aversive conditioning might have long-term effects. Research also is needed to ascertain if other predators, such as wolves (*Canis lupus*) that wander away from reintroduction sites and kill livestock, black bears (*Ursus americanus*) that depredate apiaries and livestock, and possibly tigers (*Panthera tigris*) that prey on humans in southern Asia (McDougal 1987, Sanyal 1987), might be conditioned to avoid certain prey.

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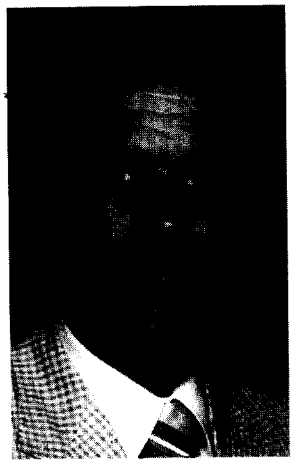

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